

$\Lambda(1520)$ and $\Sigma(1385)$ in the nuclear medium

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The $\Lambda(1520)$ as a quasibound state of $\pi\Sigma(1385)$, S. Sarkar, E. O, M.J. Vicente Vacas, PRC

$$\mathcal{L} = -i\bar{T}^\mu \not{D} T_\mu \quad (1)$$

$$\mathcal{D}^\nu T_{abc}^\mu = \partial^\nu T_{abc}^\mu + (\Gamma^\nu)_a^d T_{dbc}^\mu + (\Gamma^\nu)_b^d T_{adc}^\mu + (\Gamma^\nu)_c^d T_{abd}^\mu \quad (2)$$

$$\Gamma^\nu = \frac{1}{2}(\xi \partial^\nu \xi^\dagger + \xi^\dagger \partial^\nu \xi) \quad (3)$$

$$\xi^2 = U = e^{i\sqrt{2}\Phi/f} \quad (4)$$

$$V_{ij} = -\frac{1}{4f^2} C_{ij} (k^0 + k^{'0}). \quad (5)$$

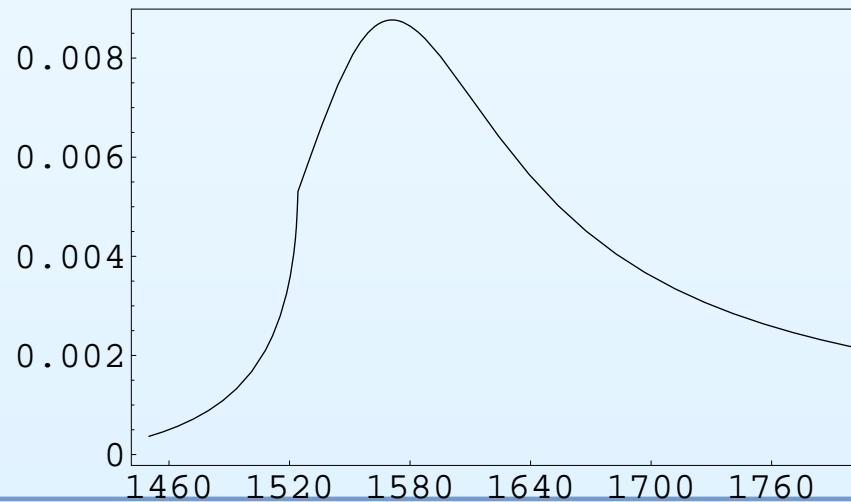
$$\begin{aligned} |\pi\Sigma^*; I=0\rangle &= \frac{1}{\sqrt{3}} |\pi^-\Sigma^{*+}\rangle - \frac{1}{\sqrt{3}} |\pi^0\Sigma^{*0}\rangle - \frac{1}{\sqrt{3}} |\pi^+\Sigma^{*-}\rangle \\ |K\Xi^*; I=0\rangle &= -\frac{1}{\sqrt{2}} |K^0\Xi^{*0}\rangle + \frac{1}{\sqrt{2}} |K^+\Xi^{*-}\rangle. \end{aligned} \quad (6)$$

C_{ij} coefficients for $S = -1, I = 0$ and $|T_{\pi\Sigma^*\rightarrow\pi\Sigma^*}|^2$

	$\pi\Sigma^*$	$K\Xi^*$
$\pi\Sigma^*$	4	$-\sqrt{6}$
$K\Xi^*$	$-\sqrt{6}$	3

$$\text{Bethe Salpeter equation } T = (1 - VG)^{-1}V \quad (7)$$

$$\text{Second Riemann sheet } G_l^{2nd} = G_l + 2i \frac{q_l}{\sqrt{s}} \frac{M_l}{4\pi}. \quad (8)$$



Introduction of the $\bar{K}N$ and $\pi\Sigma$ channels

$\bar{K}N$ and $\pi\Sigma$ couple to $\pi\Sigma(1385)$ in D-wave

$$-it_{\bar{K}N \rightarrow \pi\Sigma^*} = -i\beta_{\bar{K}N} |\vec{k}|^2 \mathcal{C}(1/2\ 2\ 3/2; m, M-m) Y_{2,m-M}(\hat{k}) (-1)^{M-m} \sqrt{4\pi}. \quad (9)$$

$$-it_{\pi\Sigma \rightarrow \pi\Sigma^*} = -i\beta_{\pi\Sigma} |\vec{k}|^2 \mathcal{C}(1/2\ 2\ 3/2; m, M-m) Y_{2,m-M}(\hat{k}) (-1)^{M-m} \sqrt{4\pi}. \quad (10)$$

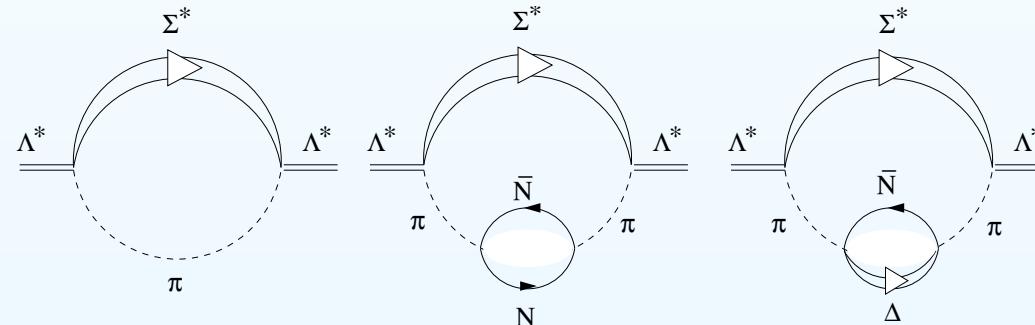
$$V = \begin{vmatrix} C_{11}(k_1^0 + k_1^0) & C_{12}(k_1^0 + k_2^0) & \gamma_{13} q_3^2 & \gamma_{14} q_4^2 \\ C_{21}(k_2^0 + k_1^0) & C_{22}(k_2^0 + k_2^0) & 0 & 0 \\ \gamma_{13} q_3^2 & 0 & \gamma_{33} q_3^4 & \gamma_{34} q_3^2 q_4^2 \\ \gamma_{14} q_4^2 & 0 & \gamma_{34} q_3^2 q_4^2 & \gamma_{44} q_4^4 \end{vmatrix}, \quad (11)$$

We chose a to get the pole at the physical position. β and γ chosen to reproduce the partial decay widths of the $\Lambda(1520)$ into $\bar{K}N$ (45%) and $\pi\Sigma$ (42%) and $\bar{K}N$ phase shifts. From residues at pole $|g_{\pi\Sigma^*}| = 0.91$, $|g_{K\Sigma^*}| = 0.29$, $|g_{\bar{K}N}| = 0.54$ and $|g_{\pi\Sigma}| = 0.45$.

$\Lambda(1520)$ in the nuclear medium

The coupling of the $\Lambda(1405)$ to $\pi\Sigma(1385)$ is very large but decay into this channel practically suppressed because of lack of phase space.

In nuclei a π can excite *ph*. Plenty of phase space. Large width.



Analogy to mesonic and nonmesonic decay of $\Lambda(1115)$ in nuclei.

$\Lambda(1115) \rightarrow \pi N$ is forbidden by Pauli blocking in nuclear matter.

But π becomes *ph* and decay possible

\rightarrow Non mesonic $\Lambda(1115)$ decay

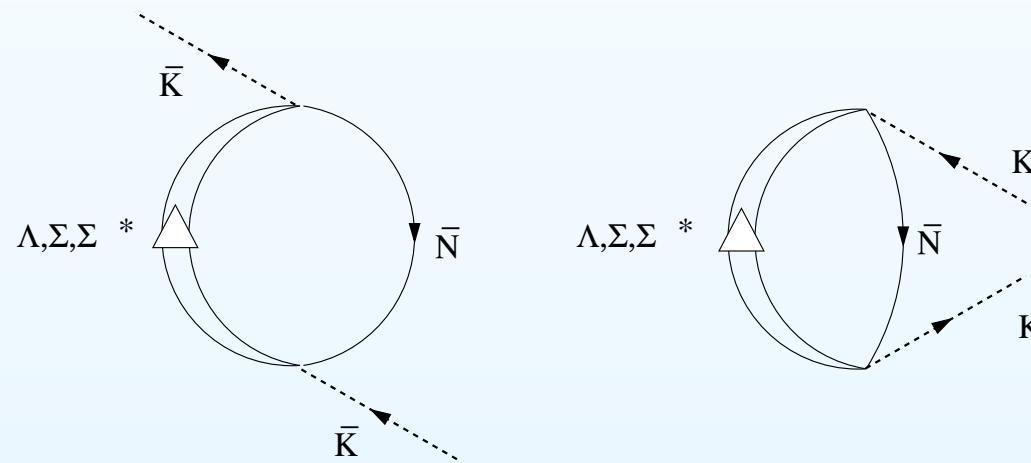
$\Lambda(1115)N \rightarrow NN$

This is much more important than the mesonic decay in nuclei.

D -wave decay of $\Lambda(1520)$ in the nuclear medium



- In-medium \bar{K} optical potential: $\bar{K} \rightarrow \Lambda\text{-h} + \Sigma\text{-h} + \Sigma(1385)\text{-h}$



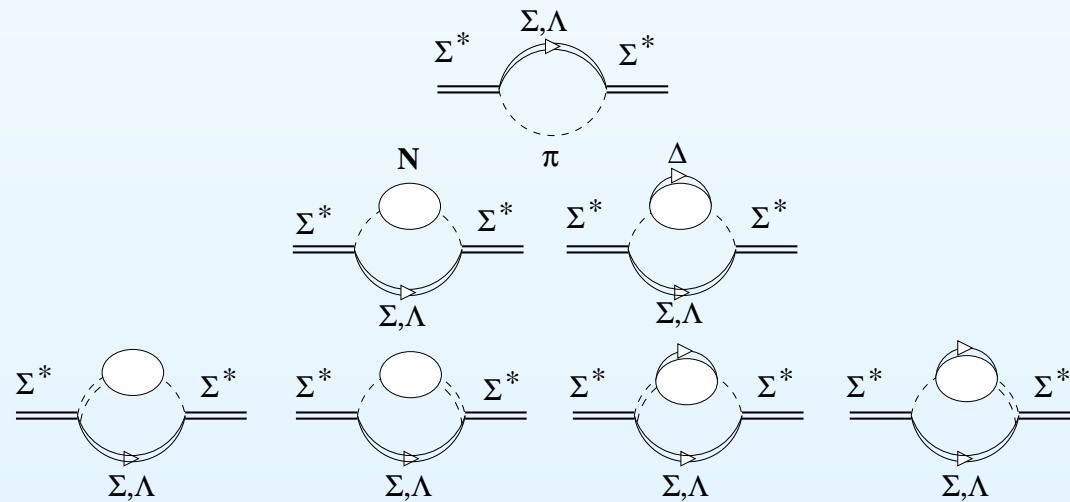
A.Ramos and E.Oset, Nucl. Phys. A 671 (2000) 481.

$\Sigma(1385)$ in the nuclear medium

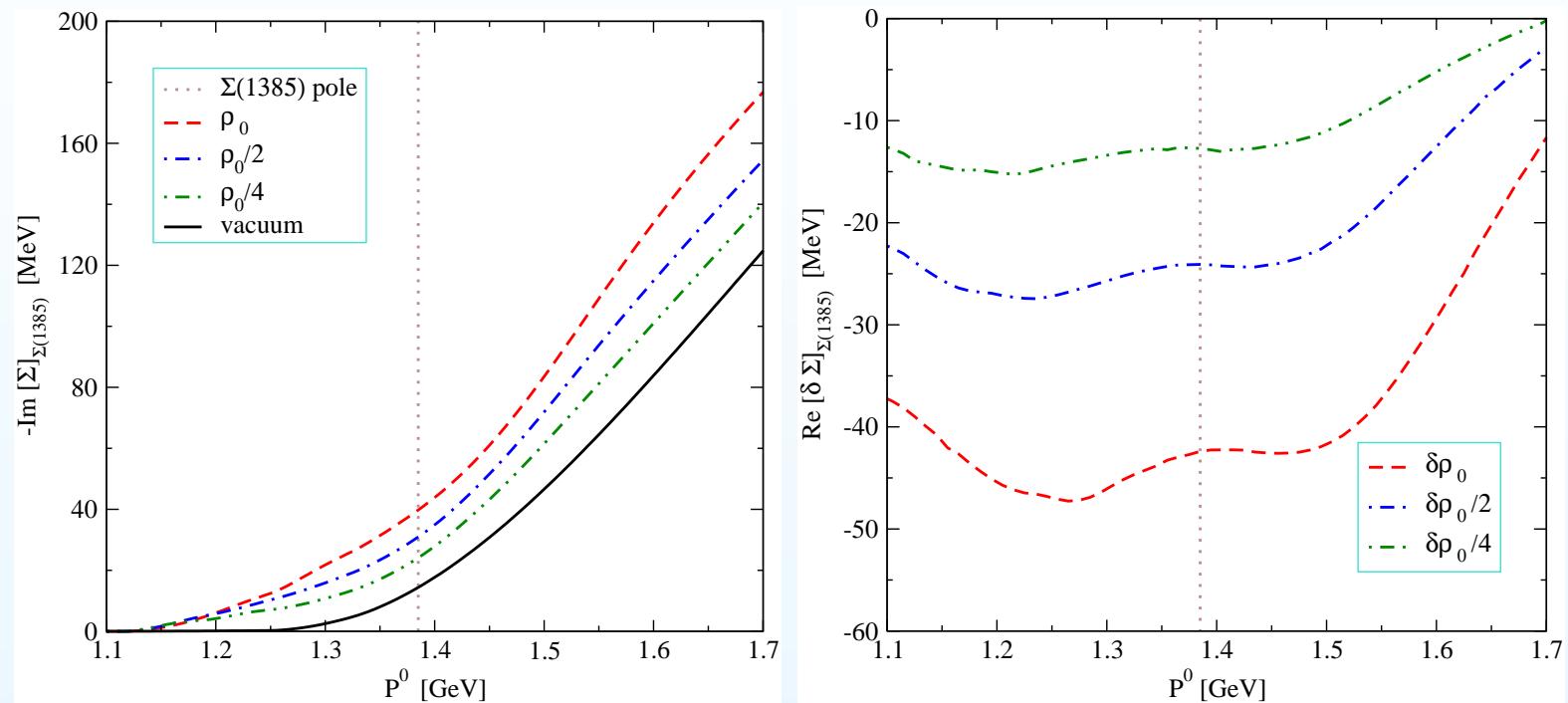
- The free width $\Gamma \simeq 30$ MeV
- Decay modes: $\Sigma(1385) \rightarrow \pi\Sigma + \pi\Lambda$

In-medium renormalization

- The pion decay $\pi \rightarrow \Delta - h + N - h$
- Short-range correlations



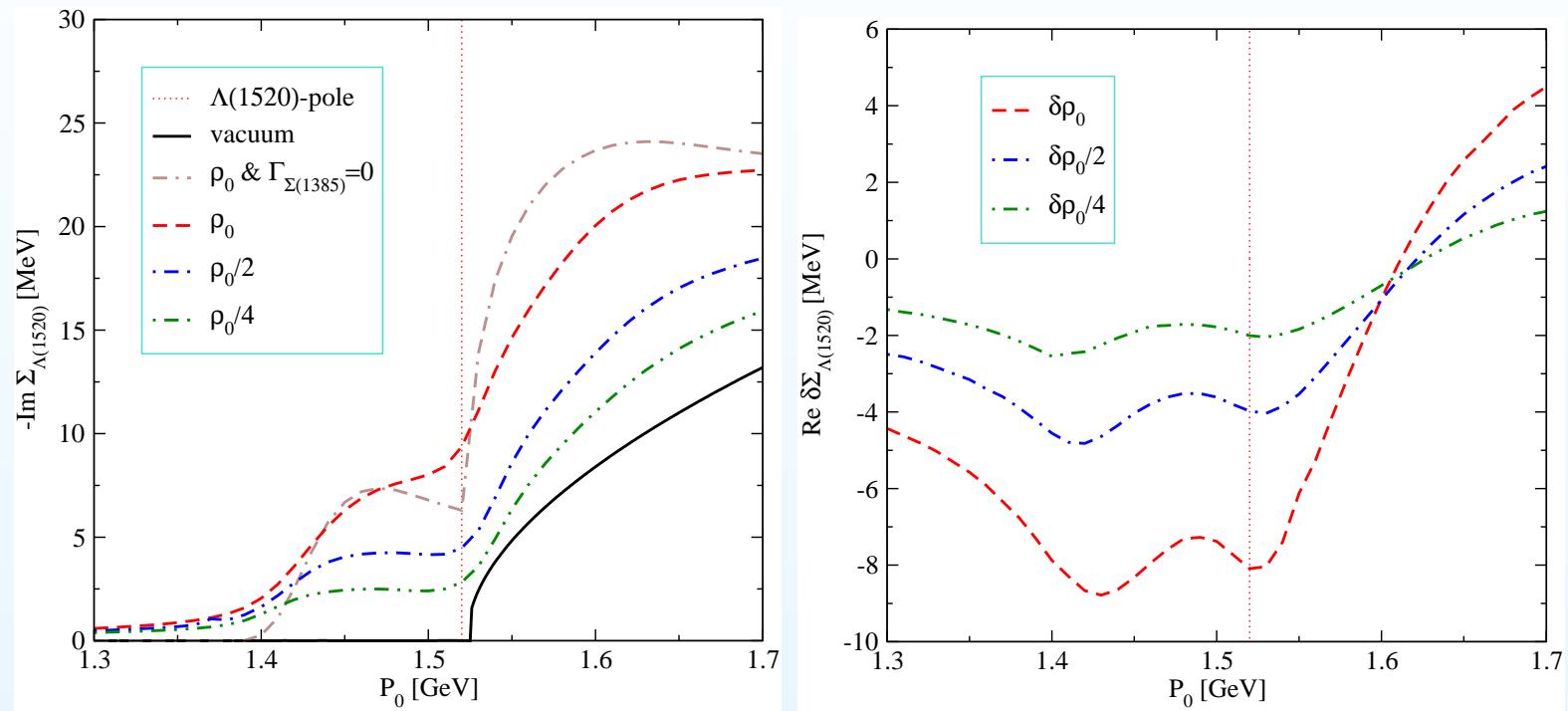
Results for the in-medium self energy of the $\Sigma(1385)$



In-medium width of the $\Sigma(1385)$ at $\rho = \rho_0$: $\Gamma = -2\text{Im}\Sigma \simeq 80$ MeV

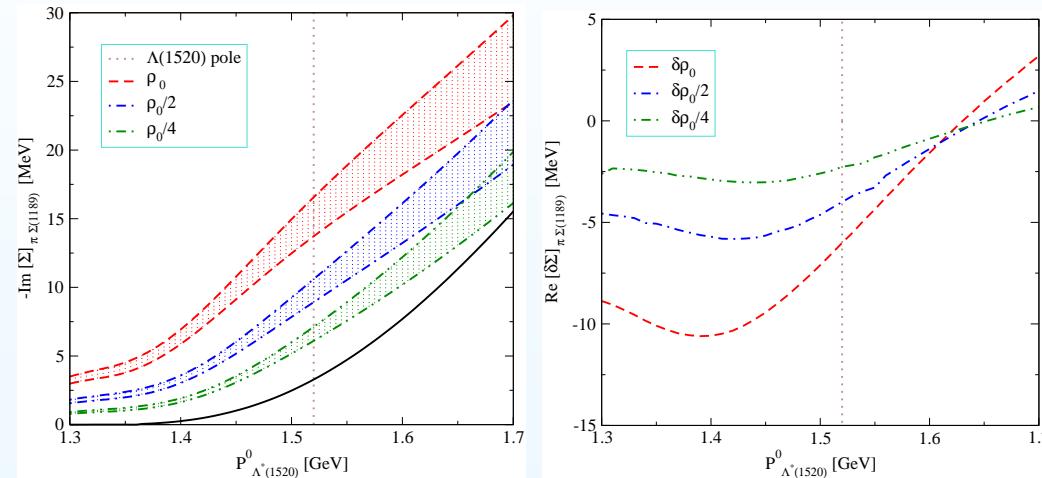
Results for the in-medium self energy of the $\Lambda(1520)$

S-wave decay: $\Lambda(1520) \rightarrow \pi\Sigma(1385)$

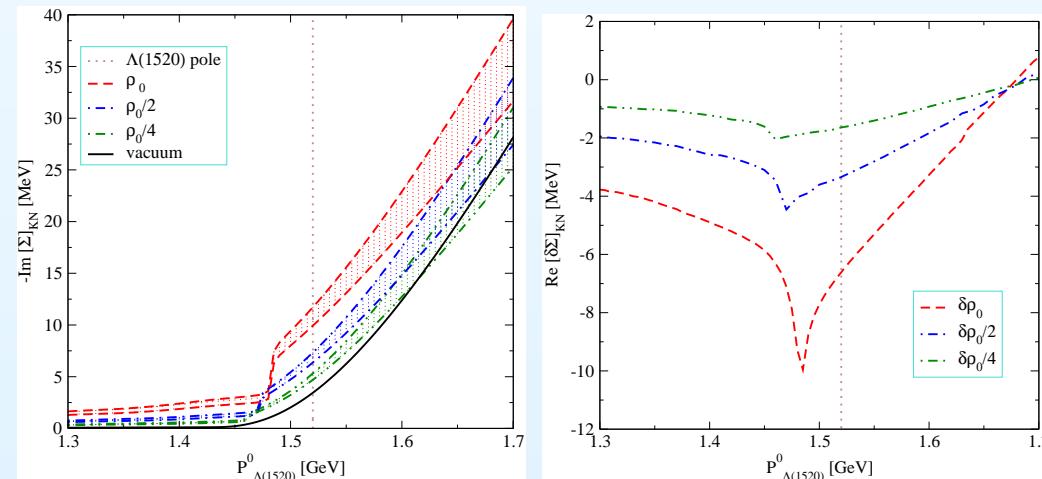


Results for the in-medium self energy of the $\Lambda(1520)$

D-wave decay: $\Lambda(1520) \rightarrow \pi\Sigma(1189)$ channel

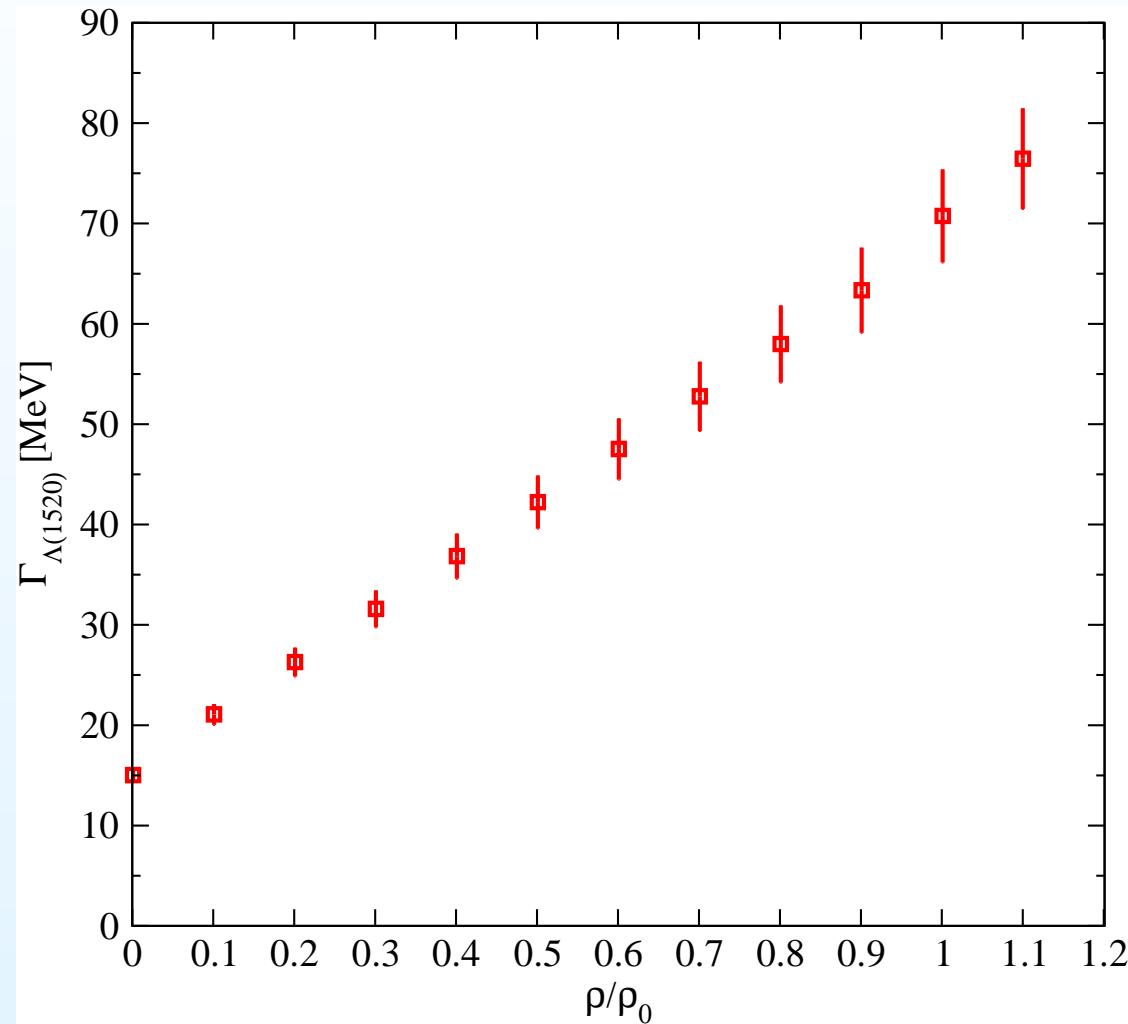


$\Lambda(1520) \rightarrow \bar{K}N$ channel



Results for the width of the $\Lambda(1520)$ in nuclear matter

$$\Gamma = -2Im\Sigma_{\Lambda}$$



Conclusions

- The S -wave decay of the $\Lambda(1520)$ into $\pi\Sigma(1385)$ is nearly forbidden in the vacuum.
- In the nuclear medium this channel opens due to the excitation of the N -h.
- In-medium S -wave + D -wave decay of the $\Lambda(1520)$ at $\rho = \rho_0$ → a big width (**5× free**).
- We also find the big renormalization of the $\Sigma(1385)$ in the nuclear medium. The in-medium width = **2.5× free**.
- **Experimental tests are feasible and welcome.**